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Title: Cross-sectional associations between body mass index and social-emotional wellbeing among differentially active children.

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Abstract

Background: This study assessed gender-specific associations between BMI and social-emotional wellbeing (SEW) among differentially active 7-year-old children.

Methods: Data is from wave four of the UK Millennium Cohort Study, collected in 2007-08. Children wore an ActiGraph accelerometer for 7 consecutive days and measures of stature and body mass were taken. BMI was calculated from stature and body mass (kg/m²). Parents/carers completed the Strengths and Difficulties Questionnaire (SDQ). Six-thousand-eleven children (3073 girls) had complete data. Mean minutes per day spent in moderate to vigorous physical activity (MVPA) were calculated for each child. Gender-specific MVPA quartile cut-off values categorised boys and girls separately into four graded groups representing the least (Q1) through to the most active (Q4) children. Adjusted linear regression analyses examined associations between BMI and SDQ scores. Gender-specific analyses were conducted separately for MVPA quartiles.

Results: BMI was positively associated with peer problems for Q1 and Q2 boys and girls, conduct problems for Q2 and Q4 boys, emotional problems and prosocial behaviour for Q2 boys, and total difficulty scores for Q1 girls and Q2 boys ($p<0.05$).

Conclusions: Our results revealed that BMI was positively associated with SEW difficulties among the low active children but not the high active children. Further research examining the concurrent effect of diet and MVPA on child weight status and SEW is needed.

Keywords: Child, body mass index, obesity, physical activity, social-emotional wellbeing.

Introduction

Childhood obesity has risen tenfold in the past 40 years [1]. In the UK, almost one third of children aged 2 to 15 years are now overweight or obese [2]. There is strong evidence linking child overweight with poor physical wellbeing [3,4]. However, less is known about the influence of child overweight on social-emotional wellbeing (SEW).

SEW relates to a child's self-perception and their ability to interact with others [5]. Children that experience SEW difficulties often demonstrate negative emotions and behaviours and struggle to maintain friendships [6]. In the long-term, SEW difficulties effect academic achievement and mental health in adulthood [7]. SEW is commonly measured using concepts of peer (e.g., being isolated from friends), and conduct problems (e.g., aggression and dishonesty), prosocial behaviour (e.g., positive social actions), and hyperactivity and emotional symptoms [8]. The Children's Strengths and Difficulties questionnaire (SDQ; [9]) provides an individual and composite measure of these five SEW concepts.

The SDQ has been used to examine associations between obesity and SEW among young [10] and older children [11,12] but reported associations have been inconsistent across studies. To date, few studies have examined associations between body mass index (BMI) and SEW [13,14], and even fewer have been undertaken in the UK. Earlier research using the UK Millennium Cohort Study (MCS) revealed an association between child obesity and SEW difficulties, and found that boys experience more SEW difficulties than girls at ages 3 and 5 years [10]. Presently, there is a lack of UK evidence relating to 7-year-old children who are at greater risk of developing SEW difficulties and obesity compared to young children [15].

Moreover, there is limited evidence on lifestyle behaviours, such as physical activity (PA) that may influence the association between child BMI and SEW.

UK children are recommended to accumulate at least 60 minutes of moderate-to-vigorous intensity PA (MVPA) each day to achieve and maintain health [16]. Some studies have reported an inverse association between PA and SEW difficulties [17,18]. Furthermore, strong evidence suggests that low active children are at greater risk of being overweight compared to their more active peers [19,20], and excess body mass is positively linked to SEW difficulties. Therefore, it may be possible for BMI to be positively associated with SEW difficulties among low active children but not among their high active peers. In this case, PA is a behaviour to promote for physical health and SEW. To fill this research gap, the present study assessed gender-specific associations between BMI and SEW among differentially active 7-year-old children.

Methods

Data is derived from wave four of the MCS. The MCS is a nationally representative UK sample of children born between September 2000 and January 2002. The sample design allowed for over-representation of ethnic minority families and families living in areas of high deprivation. The first survey was conducted throughout 2001–2002 and contained information on 18,819 children in 18,533 families, collected from the parents when children were 9 to 11 months old (MCS1). Further surveys were administered at the ages of 3 (MCS2), 5 (MCS3) and 7 years (MCS4). All measures were collected in the child's home [21]. The present study used data from MCS4 only when children were aged 7 years and PA was measured using ActiGraph waist-worn accelerometers (ActiGraph GT1M, Pensacola,

Florida) in 2007-08. Ethical approval for the original study was granted by the Northern and Yorkshire Research Ethics Committee (07/MRE03/32).

Anthropometric data and data on children's gender, age, ethnicity [22], and poverty level income [23] was collected during the home-based interview at age 7 years. Poverty was defined as having an equivalised household income below 60% of the UK median. Stature was measured to the nearest millimetre using a portable stadiometer (Leicester Height Measure, Seca, Birmingham, UK), and body mass measured to the nearest 0.1 kg using Tanita HD-305 scales (Tanita UK Ltd., Middlesex, UK). BMI was calculated from stature and body mass as a proxy measure of body composition (kg/m^2). Age and gender-specific BMI cut-points were used to classify children as normal weight or overweight/obese [24].

The Strengths and Difficulties Questionnaire (SDQ) was completed by parents during the interview and used a measure of child SEW (<http://www.sdqinfo.com/>). The SDQ has been used extensively worldwide and compares favourably with measures for identifying SEW difficulties [8,9,29]. The SDQ comprises 25 items covering five domains of behaviour including hyperactivity, emotional symptoms, conduct problems, peer problems and prosocial behaviour. Each item has three response categories: 'not true', 'somewhat true' or 'certainly true' coded as 0, 1 or 2, respectively. Higher scores on the prosocial behaviour subscale reflect strengths, whereas higher scores on the other four subscales reflect difficulties. An overall difficulties score is derived from the sum of all scales, excluding the prosocial behaviour domain. Overall scores range from 0-40 with higher scores denoting more difficulties (i.e., lower SEW).

Child PA was assessed using ActiGraph GT1M accelerometers (between May 2008 and August 2009). Full details on the PA data collection procedures have been described previously [25]. Briefly, accelerometers were programmed to record data at 15-second intervals (15-second epoch length) and delivered to participants' home addresses by mail. Children were instructed to wear the accelerometer around their waist for 7 consecutive days during waking hours, and to only remove the monitor during water-based activities. Data were downloaded using ActiGraph software V.3.8.3 (ActiGraph, Pensacola, Florida, USA). Accelerometer non-wear time, was defined as consecutive 20-minute periods of zero counts [26], and extreme count values above a threshold of $\geq 11\,715$ counts/min (cpm) were removed. MVPA and sedentary time were classified as more than 2241 and 100 counts per minute, respectively [27]. A total of 6675 children (3499 girls) met the inclusion criteria, which was classified as having at least 2 days with 10 h or more of wear-time [28]. Total time spent in MVPA for each valid day was divided by the total number of valid days for each child. Children were first classified into two groups; those who achieved more than 60 minutes of MVPA (high active) and those who did not (low active). Preliminary analyses revealed that the 60-minute MVPA threshold was not sensitive enough to classify boys and girls as low active and high active. Therefore, to explore whether the BMI-SEW association differs within low active and high active groups, gender-specific MVPA quartile cut-off values were calculated and used to categorise children into four graded groups representing the least (Q1) through to the most active (Q4) children.

Participant characteristics were analysed descriptively. Adjusted linear regression analyses examined associations between BMI and SDQ scores. Gender-specific analyses were conducted separately for MVPA quartiles. Univariate models were adjusted for poverty,

sedentary time, and accelerometer wear-time. All analyses were conducted using SPSS V.23 (SPSS Inc, Chicago, Illinois, USA).

Results

Data were available for 6011 children (3073 girls). Preliminary analyses confirmed that the data were normally distributed, and no differences were found between participants included and excluded from analyses. The descriptive characteristics of the sample are presented in Table 1. Twenty-one percent of the sample were below poverty level income ($n=1244$), 90% were white British ($n=5415$), 17% were overweight ($n=1036$), and 50% achieved the MVPA guidelines ($n=2998$).

BMI was positively associated with peer problems for Q1 boys ($B=0.07$; 95% confidence interval (CI), 0.02-0.11; $p<0.01$; Table 2), Q1 girls ($B=0.06$; 95% CI, 0.02-0.10; $p<0.01$), Q2 boys ($B=0.07$; 95% CI, 0.02-0.12; $p<0.01$), and Q2 girls ($B=0.05$; 95% CI, 0.01-0.09; $p<0.05$). BMI was positively associated with conduct problems for Q2 boys ($B=0.07$; 95% CI, 0.02-0.12; $p<0.01$) and Q4 boys ($B=0.06$; 95% CI, 0.00-0.12; $p<0.05$). Among Q2 boys, BMI was positively associated with emotional problems ($B=0.08$; 95% CI, 0.05-0.10; $p<0.001$) and prosocial behaviour ($B=0.06$; 95% CI, 0.01-0.12; $p<0.05$). BMI was positively associated with total difficulty scores for Q1 girls ($B=0.14$; 95% CI, 0.02-0.27; $p<0.05$) and Q2 boys ($B=0.30$; 95% CI, 0.13-0.47; $p<0.001$).

[TABLE 1 NEAR HERE]

[TABLE 2 NEAR HERE]

Discussion

This is the first study to examine associations between BMI and SEW in a representative sample of differentially active 7-year-old UK children. In this study BMI was positively associated with SEW difficulties among low active children but not high active children.

The strongest and most consistent association was found for BMI and peer relationship problems among Q1 and Q2 boys and girls. This finding extends beyond the findings of previous studies that have reported an association between BMI and overweight, and peer relationship problems among young children [10,14], adolescents [11,30], and 8–9-year-olds [31]. There are several potential reasons for this observed finding. For example, overweight children are more likely to experience teasing and stigmatisation from peers which can result in social marginalisation and low self-esteem [32,33]. Intuitively, being overweight and physically inactive in childhood is likely to be a stronger predictor of peer relationship problems than being overweight alone, as peer problems and victimisation are associated with low activity [33] as well as weight status [34]. Stearns et al. [30] found that peer victimisation did not mediate the relationship between overweight and MVPA in adolescent boys and girls, but observed a partial mediation for screen-time. Positive peer relations are central to healthy psychological, social and emotional child development and functioning [35,36]. Further research is needed to explore potential mediators, such as self-esteem which can result from overweight and low activity, and lead to disproportional sedentary time.

We found that BMI was positively associated with total difficulties among the Q1 and Q2 boys and the least active girls (Q1 girls). These findings are consistent with evidence in young children [10] and adolescents [37] showing that children who are overweight or have a

higher BMI have higher total difficulty scores. A UK study involving 11-14-year-old children reported a positive association between obesity and total difficulties after adjustment for age, gender and socioeconomic status [37]. However, to the best of our knowledge, this is the first study to reveal this relationship in UK children classified as low active. Perez-Bonaventura et al. [14] reported a null association in Spanish pre-school children but the study did not account for the participants' PA level which is a known predictor of weight status [19,20] and SEW [17,29]. Although treatable, SEW difficulties often go undetected and remain untreated. Our results suggest that low active children with a high BMI are at greatest risk of experiencing SEW difficulties. Therefore, screening for SEW difficulties in this population is a priority.

BMI accounted for only a small proportion of variance in SDQ scores. Studies using a categorical approach (e.g., obesity) have reported stronger associations [12]. There are several factors that may explain our findings and the variation in findings across studies. Firstly, as reported in other non-clinical populations [29], few of our participants (e.g., <5%) had an abnormally high total SDQ score. While the SDQ has been used extensively in similar populations, it was designed as a screening tool for mental health, and may be less sensitive to detecting parent-reported SEW difficulties. The variability in findings can partly be explained by inconsistencies in measures used to assess weight status and SEW. Our study focussed on BMI, and we used the SDQ which enabled investigation of independent SEW problems, revealing which of these were (e.g., peer problems) and were not (e.g., emotional, conduct and hyperactivity problems) associated with BMI. The age of the participants' investigated is another important contributing factor as older children tend to experience more SEW difficulties than younger children. The selection of confounding factors (e.g., gender, socioeconomic status, poverty) may also influence the direction and strength of

associations observed studies. Other lifestyle behaviours including dietary intake influence child SEW [38] but are seldom explored as confounding or mediating factors in this area of research. Future research in this area should investigate the concurrent effects of MVPA level and dietary intake on children's weight status and SEW.

This study has several strengths and contributions of new knowledge to the field. The study represents the first investigation of associations between BMI and SEW in differentially active 7-year-old boys and girls. The data were from a large sample representative of UK children, and analyses were performed in boys and girls classified as low and high active. Moreover, sedentary time and MVPA were assessed objectively, and analyses were adjusted for known confounding factors including poverty which is a predisposing factor to BMI and SEW difficulties [39]. The limitations of the study should also be recognised. The SDQ scores may have been subject to measurement error and social desirability bias from parents/carers and may reflect gendered stereotypes of children's behaviour. Such bias may have contributed to the inconsistent associations observed across MVPA quartiles for boys and girls. Moreover, PA was assessed over one week which may not have accurately reflected typical habitual PA. Further, hip-mounted accelerometers are unable to capture non-ambulatory (i.e., cycling) and water-based activities which may have underestimated MVPA estimates. While the sample was large the design was cross-sectional and does not determine causality.

This study demonstrates significant associations between BMI and children's SEW. Our results revealed that BMI was positively associated with SEW difficulties among low active children but not high active children. Parents of overweight low active children, especially boys, who are experiencing SEW difficulties, should be extra cautious of challenging social

experiences which may contribute to their child's SEW difficulties. Further research examining the concurrent effect of diet and MVPA on child weight status and SEW is needed.

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Availability of data and materials: The UK Millennium Cohort Study datasets are publicly available on request.

Authors' contributions: RJN designed the study, analysed and interpreted the data and drafted the manuscript. SJF contributed to the design of the study and critically revised the manuscript. Both authors read and approved the final manuscript.

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Key points:

- BMI was positively associated with SEW difficulties among low active children but not high active children.
- Peer relationship problems more common in overweight physically inactive children.

- Research examining the concurrent effect of diet and MVPA on child weight status and SEW is needed.

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Table 1 Descriptive characteristics of sample.

PA quartile and cut-off values	Boys				Girls			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
(MVPA min day ⁻¹)	<53.80 (n=734)	≥53.80-67.33 (n=735)	≥67.34-84.17 (n=734)	≥84.18 (n=735)	<42.46 (n=766)	≥42.46-53.93 (n=770)	≥53.94-66.93 (n=769)	≥66.94 (n=768)
Age (years)	7.22 (0.25)	7.22 (0.25)	7.22 (0.25)	7.23 (0.24)	7.23 (0.24)	7.23 (0.24)	7.22 (0.25)	7.20 (0.25)
White British	90.90	89.10	91.10	88.20	91.00	90.30	89.50	90.60
Poverty level income	19.80	19.00	17.80	24.10	18.30	19.90	20.50	26.00
Stature (cm)	124.08 (5.89)	124.22 (5.66)	123.81 (5.27)	124.16 (5.13)	123.24 (5.73)	123.17 (5.46)	122.84 (5.18)	123.14 (5.29)
Mass (kg)	26.18 (5.84)	25.49 (4.59)	24.83 (3.76)	25.05 (3.77)	25.37 (4.86)	25.39 (4.74)	24.91 (4.30)	24.65 (3.92)
BMI (kg/m ²)	16.87 (2.64)	16.44 (2.11)	16.14 (1.71)	16.20 (1.77)	16.61 (2.34)	16.64 (2.22)	16.43 (2.03)	16.19 (1.77)
Overweight/obese	23.20	15.60	10.50	10.90	22.10	23.90	17.80	13.50
Total valid day wear- time (min)	4018.32 (1245.79)	4243.71 (1142.72)	4226.27 (1223.24)	4203.89 (1284.44)	3812.34 (1185.84)	4056.00 (1148.37)	4076.70 (1186.33)	3971.51 (1269.22)
SED (min/day)	407.56 (44.13)	393.43 (48.14)	370.79 (47.18)	346.80 (54.46)	421.57 (40.39)	398.53 (41.96)	382.85 (48.05)	352.12 (50.99)

MVPA (min/day)	43.39	60.50	75.18	100.29	34.45	48.14	60.09	81.31
	(8.07)	(3.96)	(4.82)	(15.00)	(6.14)	(3.25)	(3.73)	(14.60)
Achieve 60 min MVPA	0.00	52.40	100.00	100.00	0.00	0.00	48.90	100.00
day ⁻¹								
Emotional symptoms	1.39 (1.70)	1.39 (1.71)	1.37 (1.73)	1.26 (1.59)	1.47 (1.59)	1.52 (1.72)	1.37 (1.62)	1.41 (1.59)
Conduct problems	1.21 (1.35)	1.28 (1.49)	1.35 (1.51)	1.45 (1.50)	0.96 (1.20)	1.05 (1.28)	1.09 (1.28)	1.17 (1.33)
Hyper-activity	3.29 (2.44)	3.36 (2.47)	3.57 (2.49)	3.76 (2.44)	2.31 (2.07)	2.53 (2.16)	2.74 (2.25)	2.99 (2.38)
Peer problems	1.28 (1.60)	1.14 (1.46)	1.02 (1.38)	1.08 (1.37)	0.95 (1.29)	0.96 (1.38)	0.95 (1.32)	0.98 (1.32)
Pro-social behaviour	8.49 (1.62)	8.46 (1.66)	8.44 (1.64)	8.50 (1.56)	9.05 (1.34)	9.02 (1.30)	8.94 (1.36)	8.90 (1.36)
Total difficulties	7.17 (5.27)	7.16 (5.08)	7.30 (5.26)	7.55 (4.86)	5.69 (4.31)	6.06 (4.71)	6.15 (4.63)	6.54 (4.72)

Study undertaken in UK (2007–08); BMI, Body mass index; MVPA, Moderate-to-vigorous intensity physical activity; SD, Standard deviation; SED, Sedentary time.

Table 2 Cross-sectional associations between BMI and SDQ scores for each MVPA quartile by gender. Adjusted regression coefficients and 95% confidence intervals.

	<i>n</i>	Emotional	Conduct	Hyperactivity	Peer	Prosocial	Total
Boys							
Q1	734	-0.01 (-0.05,0.04)	0.03 (-0.00,0.07)	0.01 (-0.06,0.08)	0.07 (0.02,0.11)**	0.00 (-0.04,0.05)	0.10 (-0.04,0.24)
Q2	735	0.08 (0.03,0.14)**	0.07 (0.02,0.12)**	0.08 (-0.01,0.16)	0.07 (0.02,0.12)**	0.06 (0.01,0.12)*	0.30 (0.13,0.47)***
Q3	734	-0.03 (-0.10,0.04)	-0.03 (-0.10,0.03)	-0.09 (-0.19,0.02)	0.00 (-0.06,0.06)	0.07 (-0.00,0.14)	-0.15 (-0.37,0.07)
Q4	735	-0.04 (-0.10,0.03)	0.06 (0.00,0.12)*	-0.07 (-0.17,0.03)	0.00 (-0.05,0.06)	-0.01 (-0.07,0.06)	-0.04 (-0.24,0.16)
Girls							
Q1	766	0.03 (-0.02,0.08)	0.03 (-0.01,0.07)	0.02 (-0.04,0.09)	0.06 (0.02,0.10)**	0.03 (-0.01,0.07)	0.14 (0.02,0.27)*
Q2	770	-0.02 (-0.07,0.04)	0.02 (-0.02,0.06)	0.01 (-0.06,0.08)	0.05 (0.01,0.09)*	0.00 (-0.04,0.04)	0.07 (-0.08,0.22)
Q3	769	-0.02 (-0.07,0.04)	0.00 (-0.04,0.05)	-0.03 (-0.11,0.05)	0.03 (-0.02,0.07)	0.05 (-0.00,0.09)	-0.01 (-0.17,0.14)
Q4	768	-0.03 (-0.09,0.03)	-0.01 (-0.06,0.05)	-0.03 (-0.12,0.07)	0.02 (-0.03,0.08)	0.04 (-0.01,0.10)	-0.04 (-0.23,0.15)

Study undertaken in UK (2007–08); * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$. BMI, body mass index; MVPA, Moderate-to-vigorous intensity physical activity; SDQ, Strengths and Difficulties Questionnaire. Univariate model adjusted for poverty income, sedentary time and accelerometer wear-time. Q1 and Q4 represent least and most active quartiles, respectively.

